Ethanol's Role: An Economic Assessment

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Expansion of the ethanol industry depends on a mix of low grain prices, stable or increasing petroleum prices through the 1990s, and assurance that subsidies for production will continue through 2000 or beyond. While expansion of the ethanol industry would increase ethanol's contribution to energy security, reduce air quality problems associated with carbon monoxide, and support farm income through increases in corn prices, alternative means of achieving these goals exist. This article assesses factors affecting ethanol's competitiveness and the tradeoffs involved in using ethanol to meet national goals.

INTRODUCTION

Alcohol fuels gained public attention during the 1970s as one solution to the "energy crisis" caused by the 1973 petroleum embargo. A search for less expensive and more reliable domestic fuel sources was hastened by an economic environment of rapidly rising fuel prices, high inflation rates, and dependence on foreign sources of energy. Alcohol produced from agricultural feedstocks offered the promise of a renewable domestic energy source which was also environmentally advantageous. The Energy Security Act of 1980 affirmed public support of alcohol fuels. A stated objective of the act was that alcohol fuel production should be equivalent to 10% of domestic gasoline consumption by 1990. For most of the 1980s, petroleum prices as well as public concern over the need to develop alternative fuels have declined. Through this period ethanol production and use, supported by a mix of Federal and State incentives, grew steadily and substantially.

Within the last few years public attention has refocused on alcohol fuels for air quality, energy security, and agricultural policy reasons. Since many metropolitan areas have been unable to meet deadlines for complying with national air quality standards set by the Clean Air Act, alcohol—blended with or used in place of gasoline—has been promoted as a pollution abatement strategy. Continuing instability in the Middle East has reinforced concerns about the vulnerability of the United States to energy supply and economic disruption from abroad. In addition, as corn prices declined and stocks grew throughout most of

CCC 0742-4477/89/050505-18$04.00

the 1980s, ethanol production using corn as a feedstock came to be seen as a way of significantly expanding the domestic market for grain, leading to increases in corn prices and, therefore, farmers' incomes.

Our aim is to provide a factual basis for assessing the contribution of ethanol production to national objectives. As a first step, an information base on the ethanol industry and production technology is developed. Estimates of current ethanol production costs and factors likely to affect costs are developed and ethanol production technology over the next 3–5 years, as well as those changes likely to affect the industry in 10–15 years, are assessed. This information is then used to evaluate the energy security, environmental, and agricultural implications of ethanol production and use.

COMPETITIVENESS OF THE FUEL–ETHANOL INDUSTRY

The US ethanol industry is composed of a diverse group of companies and production facilities. Plants in the industry vary by size, type of technology, financing, traditional grain processing experience, and diversification. A few large ethanol plants account for the bulk of ethanol production. According to Information Resources Incorporated, nearly 75% of operating capacity in 1986 was accounted for by the eight largest plants, owned by the five largest companies.[1] While over 150 fuel ethanol plants have been constructed in the United States since 1979, only 17 plants have a capacity of at least 10 million gallons per year (mgy). Most commercial plants are at least 1.0 mgy although a few on-farm plants of .05 to .5 mgy exist. We consider plants of less than 10 mgy as "small", plants in the 10–39 mgy range as "medium", and plants above 40 mgy as "large."

The Federal government has had substantial involvement in the industry. The largest government financial incentive has been the exemption of ethanol/gasoline blends from at least part of the excise tax on fuel. The excise tax level and the exemption have both risen over time. Under current law, 10% ethanol blend fuels are exempt from 6 of the 9-cent tax through September of 1993. At the 10% blending rate allowed under fuel standards, the exception is effectively a 60-cent per gallon subsidy. Many states provide similar exemptions, which average 20–30 cents per gallon.

The Federal government also implemented loan guarantee programs to assist with plant construction. Federal involvement in financing fuel–ethanol plant construction has been divided between USDA and DOE; in general, USDA has assisted smaller ethanol facilities compared to DOE. As a result USDA has guaranteed a greater number of loans, but the value of USDA loan guarantees is about one-half that of DOE. USDA has assisted 13 facilities for a total of $217 million of loan guarantees. DOE has provided loan guarantees to 3 facilities for a total value of $271 million. In addition, two of the USDA guaranteed facilities were partly funded by DOE, through cooperative agreements, for an additional amount of $35 million.

Federally financed plants constitute approximately 25% of total industry capacity. Two of the three largest dry mills and two of the eight largest plants in the industry were constructed with Federal loan guarantees. However, Federal in-

volvement has been greatest in plants with capacities of 10–39 million gallons; in this range, over 60% of capacity in the industry is federally guaranteed.

Many plants built under Federal loan guarantees have not been successful. Of the 13 loans guaranteed by USDA's Farmers Home Administration, only one company has fully paid off the loan and four are operating and making loan repayments. Of the three facilities constructed with DOE loan guarantees, only one is operating and making payments on schedule.

The implications of the high Federal loan failure rate are unclear. The Federal loan programs have several goals beyond keeping fuel–ethanol production enterprises profitable. The programs emphasize dry-mill technology, regional equity, and small-scale production. Any loan guarantee program is likely to offer the largest advantage to small, new enterprises with unproven records that are unable to obtain private financing at competitive rates.

Production Costs

The cost of ethanol production is subject to wide variation over time and varies considerably among existing plants. Large producers have a significant advantage over small producers both in terms of economies of scale in the production technology and their ability to market the fuel. Economies of scale in the production technology, while difficult to quantify because of the diverse plant configurations in the industry, continue to exist for plants with annual capacities of 100–150 million gallons. Larger producers enable the industry to compete with the petroleum and petrochemical industry and effectively market its ethanol. Ethanol production, if the industry expands considerably, will continue to be dominated by plants of at least 60 million gallons per year. A growing industry is likely to see the norm for large plants rise to 90–100 million gallons per year.

Despite the dominance of large plants, small plants with annual capacities of 0.5–10 million gallons can be profitable under special circumstances. These conditions include locating in areas with limited local grain production and high transportation costs to major grain markets, collocating with food processing or other industrial facilities where fermentable wastes are produced, or collocating with a feedlot where the byproducts can be fed directly to cattle, saving substantial costs of drying and marketing the products.

Much controversy over the cost of ethanol production is due to its dependence on highly variable corn and byproduct prices. Over the past 7 years, corn prices have varied from $1.41–$3.16 per bushel (Table I). Ethanol can be produced using either a dry-milling or wet-milling process. Byproduct sales recouped as little as 30% of the corn cost for dry mills to 90% of the cost of corn for wet mills in early 1987. Generally, corn prices fell consistently from 1981–1987, until the drought of 1988.

Byproduct prices have also varied but not nearly as much as corn prices. In recent years, byproduct prices have risen and corn prices have declined. These trends resulted in the net cost of corn, i.e., cost of corn minus byproduct prices, varying more than the cost of corn. With ethanol yields of 2.5–2.6 gallons per bushel of corn, the net cost of corn has ranged from nearly 79 cents per gallon of ethanol produced to less than 10 cents for a short period in early 1987.

Cash operating costs other than corn costs vary considerably by plant size.

Table I. Net Corn Costs of Wet and Dry Milling.

Period	Corn Cost	Byproduct[3] Value as Share of Corn Cost	Net Cost of Corn		Byproduct Value as Share of Corn Cost	Net Cost of Corn	
			Wet Milling[1]			Dry Milling[2]	
	Dollars/ Bushel	Percent	Dollars/ Bushel	Dollars/ Gallon	Percent	Dollars/ Bushel	Dollars/ Gallon
1981	3.16	44.9	1.74	0.70	41.0	1.86	71.5
1982	2.48	55.8	1.10	.44	51.5	1.20	46.2
1983	3.12	48.2	1.62	.65	44.6	1.73	66.5
1984	3.11	44.0	1.74	.70	34.0	2.05	78.8
1985	2.52	45.4	1.37	.55	33.8	1.67	64.2
1986	1.95	59.3	.79	.32	54.7	.88	33.8
1987	1.41[4]	89.1	.15	.06	78.6	.30	11.5

[1]CO_2 recovery not included; ethanol yield is 2.5 gallons/bushel.

[2]Dry distillers grain stillage and DDGS are evaluated at 125% of value of corn gluten feed, and yield is assumed to be 18 pounds/bushel, ethanol yield is 2.6 gallons/bushel.

[3]Data pertain to high fructose corn syrup byproduct streams, underestimating ethanol byproduct steam by 2.2 pounds of corn gluten feed per bushel of corn.

[4]First quarter.

Large plants spend between 40–59 cents per gallon of ethanol produced. Costs for small and midsized plants vary more markedly, 32–65 cents per gallon. The greatest outlay is for energy, averaging 36% of cash operating costs. Cash operating costs for small and midsized plants, particularly energy and labor costs, tend to be higher than for large plants by 5–10 cents per gallon. Among the reasons for higher costs: small plants are less able to take advantage of coal boiler cogeneration applications while meeting environmental regulations, economies of scale limit recovery of waste heat, and personnel costs are higher for small plants. The lowest cost ethanol producer reporting in our survey was, however, a small plant feeding ethanol byproducts wet, indicating the cost savings possible in such cases.

Estimates of capital charges, found in Table II, range from 19 cents to 48 cents. A critical assumption in calculating capital charges per gallon is the average operating level of the plant relative to rated capacity. Table II assumes plants operate at full capacity. Large plants have achieved consistent records of producing at or above rated capacity. Midsized and small plants have shown mixed operating records overall even though some have operated continuously. As an example of the costliness of below capacity production, a plant able to achieve operation at 75% capacity faces capital charges 33% higher than one operating at 100% capacity, adding from 12–16 cents to production costs for a stand-alone plant.

Combining operating, capital, and net corn costs results in the total production costs. Using these average costs, Figure 1 illustrates the effect of the variability in net corn costs on ethanol production costs. The calculated full cost of production from a stand-alone plant has ranged from as low as $0.75 per gallon with the

Table II.   Capital Cost Summary.

Capacity Addition	Capital Charge per[1] Gallon Produced (Dollars)
Incremental Addition to Operating Wet Mill	0.19–0.29
Adaption of Abandoned Oil Refinery Distillation Capacity or Wet Mill Capacity	.33– .38
New Plant	.38– .48

[1]Capital charge of 19 cents per dollar invested computed as a capital rental rate based on the following assumptions: (1) Tax Reform Act of 1986 (8-year tax life for equipment, no investment tax credit or energy investment tax credit, 38% income tax rate), (2) Nominal, pretax equity return of 15%, (3) nominal interest on loan of 8.5%, (4) debt/equity equal to 78/22, (5) annual inflation rate of 4%, and (6) an actual asset life of 30 years.

Total production cost (Dollars per gallon)

Figure 1.   Total Production Costs: Corn Prices and Byproduct Credits.

Table III.   Average Versus State-of-the-Art Operating Costs.

Cost Category	Current Average[1]	State-of-the-Art[2]
Energy	$0.17	$0.11
Ingredients, Personnel, and Maintenance	.24	.24
Management, Administration Insurance, Taxes	.06	.03
Total	.47	.38

[1]Unweighted average of large plants from industry survey.
[2]Engineering estimate for a specific plant site.

unusually high byproduct prices of early 1987 to the $1.40–1.50 range during 1981, 1983, and 1984.

Technological Improvements

Today's fuel ethanol industry dates only to 1978. Improvements in the cost and efficiency of fuel ethanol production have been made possible because of learning associated with producing a liquid fuel under a considerably different set of constraints compared to traditional beverage and industrial ethanol production. Overall, the industry measures significant savings in terms of cents per gallon of output.

Even with significant learning experienced over the life of the industry, important recent advances in production technology have only been incorporated into the production processes of a relatively small number of plants. If the most economically efficient components were integrated into a state-of-the-art plant, large production cost reductions would result. Table III indicates the advantages of using state-of-the-art technology compared to average existing technology. The state-of-the-art plant could achieve an estimated 17% reduction in operating costs, unevenly distributed among cost categories.

There are three new technologies whose potential has been demonstrated but still involve risk in commercial scale production. The first technology involves replacing yeast with the bacteria *Zymomonas mobilis*. Advantages include a faster rate of fermentation and greater temperature tolerance.[2,3] The second technology is membrane separation of solubles, which may allow 40% of the water to be separated out prior to the boiling process, greatly reducing energy requirements.[4]

Immobilization of yeasts (or *Z. mobilis*) and enzymes in the wet-mill process is the last of the promising near-term technologies. It involves passing the starch or sugar solution through a medium containing the enzymes and yeast (or bacteria). This would allow improved control of the process and maximize the use of the yeast and enzymes (or bacteria).

Technologies that may provide payoffs in the longer term include cultivation and utilization of crops such as Jerusalem artichokes, sugar beets, fodder beets, and sweet sorghum.[5] Should corn prices rise, these alternative feedstocks may prove to be cheaper because they can be grown under soil and climatic condi-

tions less suitable for corn production. The major focus of much research and development on ethanol has been in developing processes for converting cellulosic biomass materials into fermentable sugars.[6-9] The most promising technologies are those that convert herbaceous plant material including alfalfa, corn stover, and bagasse into ethanol. Current technologies are not competitive with low corn prices but much uncertainty remains. Further down the road are technologies that can convert woody plants to fermentable starches and sugars. These technologies offer a variety of chemical products whose market value is significantly greater than ethanol.[10,11] If successful, production using these technologies may result in ethanol becoming a relatively minor byproduct, with other chemical products driving production.

While it is difficult to predict cost savings associated with future technological improvements, it is likely that the state-of-the-art plant of 3–5 years in the future may obtain an additional 5-cent savings in operating costs per gallon over the state-of-the-art plant of today without substantial changes in capital costs. The best current cost estimates for producing alcohol and complimentary products from cellulose range between 1.00–1.20 per gallon compared to between $0.60–$0.90/gallon for a grain plant.[7,12]

Industry Expansion

Current industry plans are for modest capacity expansion at existing sites. Subdued interest in capacity expansion has been attributed to the expiration of the motor fuel excise tax exemption in 1993, rising corn prices resulting from drought conditions, and the projection of only modest increases in world petroleum prices.

Should production expand significantly, use of existing corn wet mills and adaptation of idle industrial capacity is likely to provide the bulk of expansion. There are many idle facilities that are adaptable to producing ethanol. Numerous abandoned corn wet mills are in Pennsylvania and New York and are, therefore, close to the Northeast gasoline market. Idle oil refineries in the Midwest, abandoned during 1981–84, have a total distillation capacity over 15 times current ethanol capacity.

The supply of abandoned facilities suitable for the expansion of the ethanol industry is large, but only the best sites among those available will have an economic advantage over new facilities. Disadvantages include constraints on the technology used, constraints on location of plant components, and poor location of the site for either corn or ethanol markets. The least costly approach for using some sites may be to raze the entire physical structure, using only the rail siding or roadway access.

Figure 2 displays potential long run supply expansion for the industry. A billion gallons of ethanol capacity may be available by adding to existing wet mills that do not have ethanol production capacity and by adding incrementally to existing ethanol production facilities. Adapting the best of abandoned industrial sites could easily add another 1–2 billion gallons of capacity or more at ethanol production costs of $1.15–$1.40, depending on corn prices. Fully new ethanol plant construction, limited to geographic areas of strategic marketing interests, can be added with costs ranging from $1.20–$1.45, depending on corn prices.
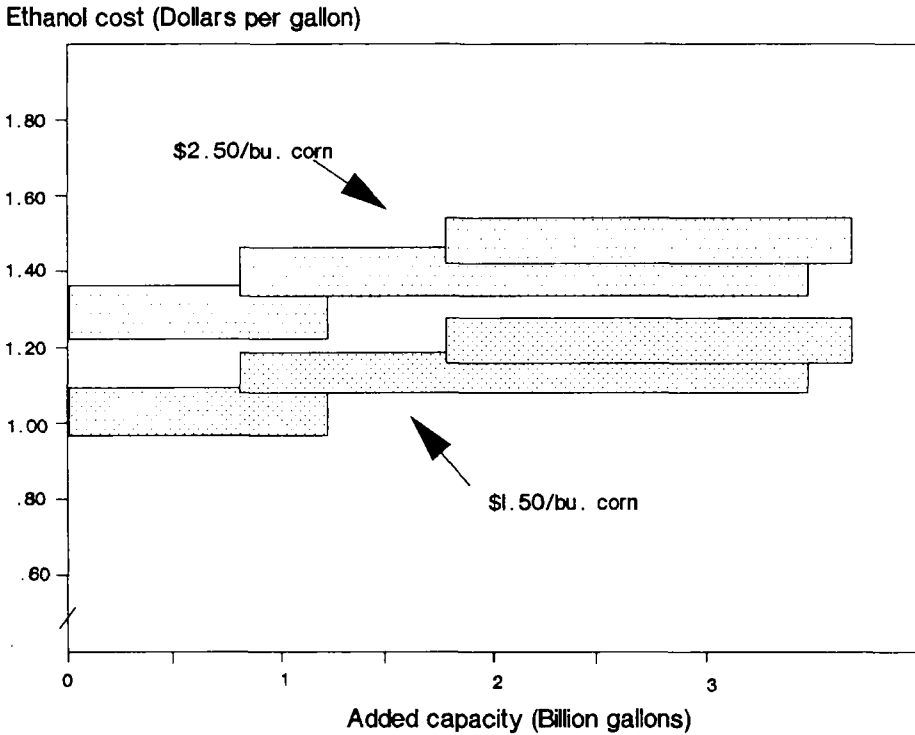
Ethanol cost (Dollars per gallon)

Figure 2. Potential Ethanol Capacity Expansion.

Cost Competitiveness with Petroleum

The cost competitiveness of ethanol depends on many factors, including how it is used in blend fuels. As a fuel extender, ethanol has a lower energy content than gasoline and vehicles using ethanol may suffer reduced mileage. Yet, ethanol added to gasoline increases octane and, therefore, competes with a variety of octane-enhancing blending agents that typically sell above the price of gasoline. Ethanol's competitive position further depends on the fuel distribution system, Federal and State subsidies, and environmental requirements. Ethanol is not directly compatible with pipeline distribution of gasoline, making it difficult for ethanol blends to penetrate markets supplied primarily by pipelines. State subsidies vary considerably. And, ethanol increases fuel volatility which has been the subject of recent EPA rulemaking.[13]

Figure 3 illustrates the effect of grain prices, crude oil prices, and production technology on ethanol's competitive position. State-of-the-art technology represents an improvement over the average existing technology and has, therefore, enhanced the competitiveness of ethanol. With $2 per bushel corn and the existing Federal subsidy, ethanol produced using average existing technology is competitive with crude oil at $22–$24 per barrel, compared with $20 per barrel with state-of-the-art technology. Further technological improvements within the next few years could make ethanol competitive at $18 per barrel crude oil. If state-of-the-art technology is utilized, but the subsidy is discontinued, crude oil prices would have to rise to at least $40 per barrel for ethanol to be competitive.
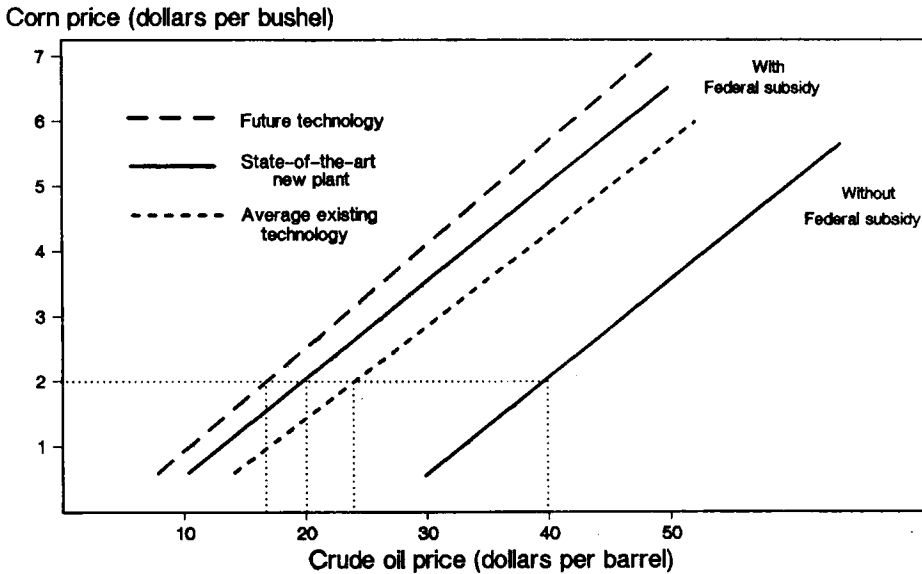
Corn price (dollars per bushel)

Figure 3. Ethanol Break-Even Curves: Technology and Federal Subsidy.

Without the subsidy, and using average existing technology, ethanol would not be competitive with petroleum when petroleum prices are below $25 per barrel unless byproduct credit exceeds the cost of corn.

ETHANOL IN US ENERGY POLICY

A primary goal of US energy policy has been to assure energy security. Major policy initiatives for long-term energy security have been aimed at research and development and at assuring timely commercial production of alternative fuels based on plentiful domestic resources. Energy policy, in attempting to foster energy security, has led to large subsidies to all energy industries, including ethanol.

Reduced dependence on foreign supplies is one broad policy response to energy security concerns. Yet, reduced dependence has limited energy security value. Energy independence gained by forcing consumption of relatively expensive domestic fuels retards economic growth by raising energy expenditures, either directly or through taxation, at the expense of savings and investment. A less vigorous economy may compromise national security in the longer run. Energy independence also would hasten the depletion of domestic nonrenewable natural resources, leading to either a return to energy dependence or rising costs of maintaining independence.

Even with reduced dependence, international energy shocks would reduce global income and output which would affect the United States through international trade.[14,15] Lower income abroad reduces demand for US exports, hurting domestic export industries and inducing ripple effects throughout the US economy.

While energy independence has limited value pursued for its own sake, the

development of cost competitive fuel-producing industries through research, development, and commercialization of promising technologies offers significant advantages for overall US competitiveness. Successful energy industries, based on US coal or shale oil resources, could result in the United States becoming a net energy exporter in the next century as conventional petroleum supplies dwindle abroad. Current support for ethanol, synfuels, and other advanced energy technologies can be evaluated from this perspective.

The relative level of support that can be justified for individual fuel-producing technologies depends on the potential supply available, accounting for both the quantities of fuel and the prices at which the fuel would be available. Biomass fuels generally do not compare well with future cost and quantity estimates for many other technologies. Liquid fuels from coal and shale oil appear likely to be less expensive and available in unconstrained quantities for the next 100 years or more. Tar sands and further efforts at enhanced oil recovery, while somewhat limited in terms of quantity, can provide a significant contribution to conventional oil production.

The cost range for ethanol reflects uncertainty and future upward pressure on ethanol feedstocks. Even with further development of crops or silviculture that produce high levels of dry matter per acre and breakthroughs in cellulosic conversion processes, the cost of large-scale biomass use would remain high in terms of traditional inputs and in terms of disruptions to the environment.[16] The more successful ethanol is in contributing to long-term energy supplies, the more it will drive up feedstock prices and its own cost of production. Thus, ethanol production tends to limit itself to the role of a small fuel contributor using temporary agricultural surpluses and organic waste.

Energy Subsidies

The Federal Government has provided large subsidies for development of all energy resources (Table IV). Interpretation of relative subsidy levels has been controversial. Many energy resource and technology categories, including crude oil, coal, and nuclear fission, contain research and development (R&D) projects that had little or no attributable output in the year the funds were spent. Ethanol subsidies have elements of both R&D funding and direct production supports. The industry contributes to current energy supplies, but remains a very young industry.

Ethanol is highly subsidized when compared with other fuels. Tax expenditures related to ethanol production were nearly $1 billion in 1986, surpassing R&D funding for synthetic fuels or nuclear fusion. The 1984 ethanol subsidy of nearly $15 per billion Btu's is an order of magnitude larger than the $.50 per million Btu's subsidies for petroleum, natural gas, and coal. Subsidies for nuclear fission approach the ethanol subsidy level, per unit of fuel produced.

ENVIRONMENTAL EFFECTS OF ALTERNATIVE FUELS

In response to environmental concerns, many parts of the country have experienced renewed interest in alternative fuels. The approaching compliance dead-

Table IV. Energy Incentives and Production (1986 Dollars).

Energy Resource/Technology	1977		1984	
	Incentives	Production	Incentives	Production
	Million Dollars	Quadrillion Btu's	Million Dollars	Quadrillion Btu's
Crude Oil and NGL	21,307	17.315	496	20.957
Natural Gas	−1,467	21.907	4,953	17.750
Coal	1,843	15.926	3,664	19.696
Synthetic Fuels	[1]	0	692	0
Nuclear	2,820	.856	17,013	1.11
Fusion	[1]	0	651	0
Electricity[2]	8,101	7.247	7,689	6.002
Hydroelectric	610	.752	2,823	1.096
Other Renewable Resources[3]	ND	0	1,822	2.929
Energy Conservation	ND	ND	928	ND

[1] Not separately identified.

[2] There are some differences in the 1977 and 1984 categories. For 1984, electricity is broken down by fuel, including nuclear, hydroelectric, and fossil. For 1977, specific nuclear- and hydro-related expenditures are identified.

[3] Including ethanol.

ND = Not defined.

Source: Cone and others, 1980; Heede, 1985.

lines for ambient standards set by the amended Clean Air Act and a perception that using alcohol in vehicle engines may lead to "painless emission reduction" have created broad-based interest in alcohol fuels.

Blended alcohol fuels are sufficiently similar to nonalcohol gasoline to allow most vehicles to be able to use them without modifications in engine designs. However, blended fuels consist primarily of gasoline, which limits the potential benefits, both emission control and efficiency, of the additive.

The amended Clean Air Act requires that concentrations of lead, sulfur dioxide, nitrogen dioxide, ozone, carbon monoxide, and particulate matter not exceed the national ambient air quality standards set by the EPA. The act requires States, in areas where concentrations of the six pollutants exceed the standards, to develop State implementation plans to control emission sources to meet the standards. Levels of lead, sulfur dioxide, and nitrogen dioxide are nearing the desired standards, but serious ozone and carbon monoxide problems still exist in many areas.[17]

The use of alternative fuels will directly affect motor vehicle emissions. EPA attributes 66% of all carbon monoxide emissions to imperfect combustion in motor vehicle engines.[18] This percentage exceeds 80% in many urban areas. Motor vehicles also significantly increase the ambient ozone pollution. Ozone is not directly emitted by vehicles but forms in the air by the reaction of volatile, organic compounds in the presence of sunlight. The level of ozone-producing compounds emitted by vehicles varies considerably among cities.

From 1976 to 1985, national carbon monoxide levels declined 36%, with the

greatest declines recorded in recent years. Ozone pollution, a summertime prob-
lem, has shown a decline over the 10-year period to about the mean level called
for by the standard. Unlike the carbon monoxide trend, the ozone trend line lies
above the EPA goal throughout the 10-year period.[13,19]

The magnitude of the nonattainment problem is presently similar for both
ozone and carbon monoxide. However, by 1995 fewer than 50% of the urban
areas now exceeding the ozone goal are expected to comply, compared to 80–
90% of the urban areas currently exceeding the carbon monoxide goal.

Adding ethanol or methanol to gasoline increases fuel volatility and thus
increases the amount of evaporative hydrocarbon emissions. At 10% or less blend
levels for ethanol or methanol, fuel volatility as measured by Reid vapor pressure
increases by 1–2 pounds per square inch. The presence of alcohol in the blend
leads to more evaporation of gasoline components than when the gasoline is not
blended. Without compensating changes in fuel processing to reduce volatility,
the widespread adoption of alcohol fuels would increase the evaporation problem
and local ozone levels. Potentially increased ozone formation would be a particu-
larly important problem in the warmer months in most parts of the country, and
almost all year in southern California, parts of Arizona, and the Gulf Coast States.
Because ozone formation in the atmosphere results from the complex interaction of
man-made and natural phenomenon, ozone is considered to be a more difficult
pollution problem to treat than carbon monoxide.

A few states have passed mandatory oxygenated fuels programs, including
Arizona and Colorado, and many more are considering the mandated use of
oxygenates to facilitate compliance with EPA's standard for ambient carbon
monoxide levels. In 1987, the Colorado Air Quality Control Commission coordi-
nated the first mandated winter oxygenated fuels program in the US designed to
reduce ambient levels of carbon monoxide and particulate emissions. By limiting
the program to the winter months, the summer ozone problem in Denver and
other areas in Colorado's Front Range is not expected to intensify due to the
increased fuel volatility from ethanol blends. Oxygenated fuels programs are only
one piece of a larger package of measures designed to reduce carbon monoxide
pollution. Even with the implementation of innovative programs, like oxygenated
fuels programs, to reduce carbon monoxide levels, none of the areas currently out
of compliance are expected to meet the standards any time soon.[20]

Much controversy exists over the ultimate contribution of oxygenated fuels
programs. The use of blended gasoline may initially decrease carbon monoxide
levels 3–10% at sea level and as much as 20% at high altitudes. Nevertheless,
the rate at which carbon monoxide levels continue to decline may slow as
population and the number of vehicles grow, and may actually increase in these
areas in the longer run.

ETHANOL AND AGRICULTURE

The significance of ethanol production for agriculture depends on commodity
market conditions, the nature of farm programs, and the size of the ethanol
industry. With favorable market conditions for corn, ethanol production would
have a greater effect on commodity production and farm income than when
market conditions are soft (low prices and large stocks). In times of low export

demand, ethanol takes on added importance as an alternative demand for corn. In such cases, an expanded grain demand by the fuel ethanol industry can partially substitute for more traditional agricultural programs that have relied on price supports, supply controls, and grain reserves to reduce excess domestic supplies.

The level of ethanol production depends on petroleum prices, legislation on energy and environmental quality, and future ethanol production technology, in addition to the status of government production incentives. Given uncertainty in petroleum markets, government policy formulation, and technological change, no one future path of ethanol production can be predicted with confidence. We simplify the task of projecting ethanol production by constructing three representative ethanol production scenarios.*

In the case where oil prices center around $20 per barrel and the gasoline excise tax exemption expires in 1993, the industry could be expected to grow slowly and eventually decline. The Low Growth Scenario depicts ethanol production from 1988–93, at 1.1 billion gallons annually, declining substantially by 1995. If mandated levels of ethanol reached 2–3 billion gallons annually, oil prices rise to $30–40 per barrel, or ethanol production costs drop modestly to $.80–$1.00 per gallon, the industry could be expected to grow moderately. The Moderate Growth Scenario depicts growth of about 13% per year, with ethanol production increasing from .95 billion gallons in 1987 to 2.7 billion gallons by 1995.

Under an unusually high level of mandated use of ethanol, high petroleum prices, or low ethanol production costs resulting from a technological breakthrough, ethanol production could increase dramatically. The High Growth Scenario is characterized by rapid growth of the industry, about 20% annually, with ethanol production rising to 4.4 billion gallons by 1995.

Corn Market Effects

The primary effect of increased ethanol production is to increase corn prices. The size of the increase depends on how much corn is demanded by ethanol producers and the ability and willingness of farmers to shift acreage to the production of corn. Depending on the market price of corn and the set of government incentives in place, farmers would be expected to increase their planting of corn at the expense of soybeans. Farmers will make the shift because expanded ethanol production increases the price of corn and ethanol byproducts reduce the demand for oilseeds, including soybeans, cottonseed, and sunflower seeds. Falling prices for these crops further enhance the relative profitability of corn.

The magnitude of corn price increases depends directly on the level of ethanol production and the amount of corn demanded by the ethanol industry. Given current ethanol industry expectations of financial losses after the expiration of the Federal excise tax exemption in 1993, economic incentives exist for only minor capacity expansion. Limited expansion would likely result in an output

*Because the agricultural sector is complex, a statistical model, AGSIM, was used to assist in the analysis of the effect of ethanol production on agricultural production, prices, and farm income.[21–23]

level of 1.1 billion gallons of ethanol produced within the next few years. Additional corn demand of up to 140 million bushels, predicted under the low growth scenario, could result from slow expansion and would have a negligible effect on corn prices.

If favorable profit conditions for producing ethanol persisted through the 1990s, the ethanol industry could enjoy a larger expansion to a production level on the order of 2.5 billion gallons by 1995. Additional corn demand of nearly 800 million bushels, projected under the moderate growth scenario, could increase corn prices 50 cents per bushel in the near term with the price effect moderating to 35 cents as corn production and the agricultural sector adjust.

An intense ethanol development program spurred by additional incentives, mandates, or other government actions might achieve an ethanol production level of over 4.0 billion gallons by 1995. Under such a high growth scenario, the corn price effect could be as much as $1.10 per bushel in the short run, moderating to 70 cents in the long run. High levels of development would stretch the ability of ethanol producers to expand and would require significant financial incentives to justify marshalling the necessary investment resources.

Effects of Oilseeds and Protein Meal Markets

Ethanol production increases the supply of high-protein animal feeds, thereby directly influencing oilseed and protein meal markets. The dry milling process for ethanol production generates about 18 pounds of distillers dried grains for every bushel of corn converted to ethanol. The wet milling process generates 2.5 pounds of gluten meal (60% crude protein), 12.5 pounds of gluten feed (20–21% crude protein), and germ which is converted to 1.6 pounds of corn oil for each bushel of corn.

Oilseed and protein market prices are negatively affected by increased levels of ethanol production. Ethanol production of 2.5 billion gallons would generate 5 million tons of ethanol byproducts (measured on a soybean meal protein-equivalent basis), equalling 20% of current soybean production, and 831 million pounds of corn oil, equalling approximately 7% of domestic oil production.

The potential impact on oilseed and protein markets would be offset by the reduction in supply as farmers switch to more profitable corn production. For large increases in ethanol production, soybean market prices may initially decrease by 20%. However, as farmers substitute corn for soybean acreage, soybean supply would shrink and offset the fall in soybean prices. Corn prices relative to soybean prices would ultimately move back toward their long-term relationship which reflects relative production costs.

Byproduct Markets

Domestic feed markets could absorb all the ethanol byproducts from a large ethanol program, but market prices would reflect the energy rather than the higher valued protein content of the byproduct. These lower prices would increase ethanol production costs by reducing byproduct credits against the price of grain. Under high levels of ethanol production, unrestricted export markets

would be needed to maintain byproducts value as protein substitutes. The likelihood that byproduct feeds would receive a protein-equivalent price decreases significantly if export opportunities were restricted and ethanol production expands significantly.

The European Community (EC) is the largest foreign market for gluten feeds. The United States is the largest supplier of gluten feed to the EC, accounting for over 95% of its imports. Corn gluten feed currently enters the EC free of tariffs and duties, unlike corn where prices have been pushed to $5 per bushel. Recent GATT sessions indicate a restrictive mood in the EC and the possibility of placing duties on byproduct feeds is being discussed. In October 1984, the EC's Commission proposed to limit annual imports of corn gluten feed to 3 million metric tons, 1 million less than current annual US exports. By restricting corn gluten feed imports, the EC Commission hopes to limit the availability of inexpensive feeds to livestock and dairy producers. Limits on imports would support the demand for grains produced in the Community. The effect on the United States would be to reduce the value of ethanol byproducts and reduce the profitability of producing ethanol.

Farm Income

Current farm commodity programs buffer effects of changes in market prices on farm income. Higher market prices received by farmers are offset by lower deficiency payments. When market prices are low relative to target prices and program participation among farmers is high, modest changes in commodity prices have little effect on farm income. In such a situation, ethanol production could have significant income effects for farmers who do not participate in farm programs. Income for grain producers who participate in farm programs does not materially increase as prices increase until the market price for the commodity exceeds the target price.

Changes in total farm income are also moderated by differential effects among grain, oilseed, and livestock producers. Whereas increased demand for corn by ethanol producers increases corn prices, the generation of high-protein byproducts decreases the price of soybean and other oilseeds. As a group, grain producers may increase their income, but livestock producers, who must pay higher grain prices, may lose.

Moderate levels of ethanol production would have relatively small effects on aggregate farm revenue and income. In the absence of production or demand aberrations, it is unlikely that modest increases in ethanol production would lead to market prices for corn that would exceed current target price levels within the next 8–10 years. By 1995, annual gross receipts (production multiplied by price) from crop production could increase by $1–$2 billion for 2–3 billion gallons of ethanol production.

Changes in crop prices also affect revenue and net income for livestock producers. Even though producers who avoid higher corn prices could increase their incomes, revenue and income changes are minor for all animals. In the aggregate, net income to livestock producers would decline by less than $1 billion for moderate levels of ethanol production.

The total effect of ethanol production on farm income is obtained by combining

the effects on crops and livestock. Increased ethanol production would increase net farm income. Losses to livestock producers are offset by crop gains. Among crop farmers, those specializing in corn, sorghum, and wheat gain while those specializing in soybeans or those who combine cotton and soybeans lose. If ethanol production grew moderately to about 3.0 billion gallons within the next decade, total farmer gains would be less than $1 billion dollars.

CONCLUSIONS

Incremental reductions in the future cost of producing ethanol due to improved technology are expected but reductions that would offset the loss of the Federal tax exemption are unlikely. A state-of-the-art plant built today can achieve 9-cent per gallon, over 15%, operating cost savings over the average industry costs; some firms approach state-of-the-art cost levels today. The state-of-the-art plant of 3–5 years in the future will most likely only achieve an additional 5 cent savings in operating costs per gallon over the state-of-the-art plant of today.

Looking ahead 5–10 years, converting cellulose and processing other renewable resources into oxygenated fuels and chemicals will remain a major challenge to agricultural product utilization research. The time-frame for bringing these technologies on-line depends on research and development in the cultivation, processing, and fermentation of cellulosic materials in addition to the emphasis on fundamental research in transformation of the resources into value-added products.

Under favorable conditions for expansion, as much as 1 billion gallons of capacity could be added for about half the cost of a new plant through incremental additions at existing ethanol facilities and at operating wet mills. Another 1–2 billion gallons could be added to the industry by adapting abandoned industrial oil refineries and wet mills at 10–25 percent less than the cost of a new plant.

Expansion of the ethanol industry depends on a mix of low grain prices, stable or increasing petroleum prices through the 1990s, and assurance that subsidies for production will continue through 2000 or beyond. Prospects of only modest increases in the price of crude oil well into the 1990s means that industry expansion hinges largely on extension of the Federal excise tax. For ethanol to be competitive in the 1990s without the Federal subsidy, crude oil prices would have to rise to nearly $40 per barrel or more with corn prices at or below $2.50 per barrel.

Ethanol production is self-limiting in terms of its contribution to national energy supplies. The broader range of ethanol feedstocks envisioned for the future offers greater production potential but they are constrained and relatively costly in terms of delivered energy content, compared with other long-term liquid fuels based on abundant domestic resources such as coal and shale oil.

Ethanol use can help meet certain requirements of the Clean Air Act. Even though ethanol blended at 10% with gasoline has been demonstrated to reduce vehicle carbon monoxide emissions, it may lead to increases in ozone concentrations that are also limited by the Clean Air Act. Carbon monoxide reductions from alcohol blend fuel use are expected to have the greatest effect in the short-run. Growth in population and the number of vehicles in the future could offset enhanced emission reductions.

The operation of government commodity programs and differential and offsetting effects among crop and livestock producers, suggests moderate growth in ethanol production would have relatively small effects on aggregate farm revenue and income. Moderate to large increases in ethanol production would increase net farm income, with losses by livestock producers offset by gains to crop producers. Those farmers specializing in corn, sorghum, and wheat would fare better than those specializing in soybeans, or those who combine cotton and soybeans. Total gains by farmers under high levels of ethanol production could reach between $2–$4 billion and less than a billion dollars if ethanol production increased only moderately by 1995.

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